Processes Affecting Exchange of Mud between Tidal Channels and Flats

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LONG-TERM GOALS

The goal of our Tidal Flats research is to expand our understanding of the erosional and depositional processes that lead to exchange of mud between tidal channels and tidal flats. We also investigate the effect of sediment texture on sediment strength.

OBJECTIVES

Our research on Tidal Flats DRI had three primary objectives:

1. Improve understanding of how turbulence and sediment concentration affect the size-dependent depositional flux of sediment to the seabed on tidal flats. Based on our observations during the project, this objective has been broadened to include the effect of rainfall and runoff.
2. Improve understanding of how sediment texture and sorting in the seabed affect the size-dependent erosional flux from the seabed on tidal flats.
3. Link our understanding of erosional and depositional sorting to spatial and temporal patterns of grain size on tidal flats.

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APPROACH

We have collected three types of data at the southern end of Willapa Bay, WA. We have conducted regional grain size surveys along a transect extending from the muddier southeast portion of Shoalwater Bay near Round Island to the sandier northwest portion (Figure 1). We have measured suspended particle properties with a set of instrument pods deployed simultaneously in a secondary tidal channel and the adjacent flat (Figure 2). The instruments carried on the pods were 2 LISST-100X laser particle sizers, 2 digital floc cameras (DFCs), a digital video settling column (DVC), and a McLane in situ water transfer system. We also deployed AquaDopp acoustic current meters with each set of pods. To examine erodibility and erosional sorting, we have collected and eroded sediment cores with a Gust erosion chamber.

Hill, Law, and Milligan collaborate closely on all aspects of this project. John Newgard (Dal) and Vanessa Page and Tina Lum (BIO) provide support in the lab and field. Undergraduate student Jessica Garwood (Dal) provided support for the project. She completed her undergraduate Honours thesis on the effect of biofilms on sediment sortability on a local tidal flat. This work links closely to the sediment sortability research in Willapa Bay.

We collaborate closely with several other PIs in the tidal flats group. We share cores and erosion data with Pat Wiberg (UVA). We work closely with Rob Wheatcroft (OSU) on sample collection, and we share data on sediment properties. We provide Bernie Boudreau and Bruce Johnson with cores and grain size data. We coordinate our sampling plans with Chuck Nittrouer and Andrea Ogston (UW).

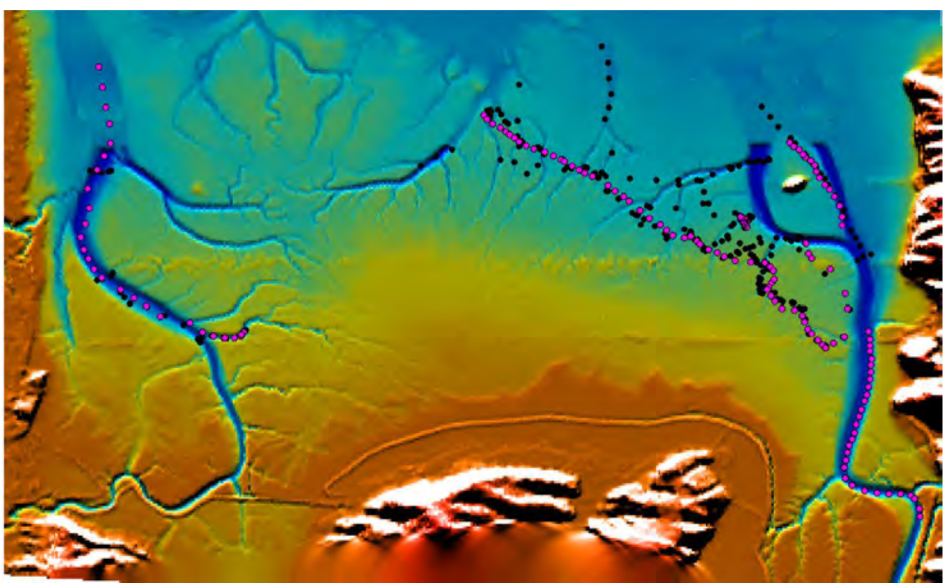

Figure 1: Sample location map for Willapa Bay Tidal Flats sediment survey. Dark symbols show analyzed grain size sample locations of surveys in September 2008 and March and July 2009 and February 2010. Pink symbols show sample locations of the most recent survey in July 2010. Color indicates flat elevation obtained from a 2002 NOAA Lidar survey. Image is ~4km wide.

WORK COMPLETED

Four major tasks were completed during the report period:

1. Analysis of February/March 2010 data;
2. Preparation and submission of two papers to the Tidal Flats Special Volume;
3. Collaboration on two other Tidal Flats Special Volume papers;
4. Preparation of another paper on controls on floc size, to be submitted autumn, 2011.

Figure 2. Instruments on the Willapa Bay tidal flat. From left to right, Digital Settling Velocity Camera (DVC), LISST 100x, Digital Floc Camera (DFC), and 2 Nortek Aquadopps.

RESULTS

Several basic results have emerged from our work.

- Extent of flocculation in bottom sediment decreases as one moves from the channels to the flats (Figure 3). This trend is important because flocculation produces poorly sorted, fine sediments in the seabed, which are most likely to have low permeability, high water content and low strength.

- Maximum flow speeds on the flood and ebb tides occur as water invades and evacuates the flats. Flood and ebb velocity pulses occur in the channels but not on the adjacent flats. Flocs eroded from the channel during the flood pulse deposit at high slack water, are resuspended as water recedes from the flats, and then deposit again after water leaves the flats (Figure 4). These processes make the channels and channel edges the sites of frequent floc deposition and erosion, causing low sediment strength.

- Floc fraction in bed sediments is larger in the channels in winter than it is on the flats. In summer floc fractions are similar in the channels and on the flats. The seabed texture in winter is consistent with the observed suspended sediment dynamics in winter.

- Size and concentration of flocs in suspension are linked to tidal range through two effects. First, large tidal range results in resuspension of larger flocs from channel floors. Second, elevated concentrations associated with stronger currents increase aggregation rate, leading to the formation of large flocs at slack water.

- Size and concentration of flocs are linked to rainfall and runoff. Runoff introduces fine material into suspension that eventually, over time scales of days, is incorporated into larger flocs.

IMPACT/APPLICATION

Variability in seabed properties represents a major concern for safe and efficient travel across tidal flats. People and equipment can sink deeply into muds with large water contents, making travel difficult and potentially dangerous. The link between seabed properties and "trafficability" motivates efforts to understand the formation of low-strength, high-water-content muds so that models that predict the locations of such deposits can be developed. Our work suggests that in winter, high-water-content muds will be found in and on the flanks of secondary channels. High-water-content muds are less common in summer, likely due to limited sediment supply associated with low rainfall and runoff.

RELATED WORK

Results from the in-situ measurement of particle size, beam attenuation (c_p), and settling velocity are being applied to the ONR funded Ocean Optics OASIS project. The two LISSTs used in this project were purchased with Canadian funds, one from a project on oil-mineral aggregation (NSERC, Hill) and one on particle transport away from finfish aquaculture sites (DFO, Law).

REFERENCES

Curran, K. J., P. S. Hill, T. M. Schell, T. G. Milligan, and D. J. W. Piper, 2004. Inferring the mass fraction of floc-deposited mud: Application to fine-grained turbidites. *Sedimentology*, 51: 927-944.

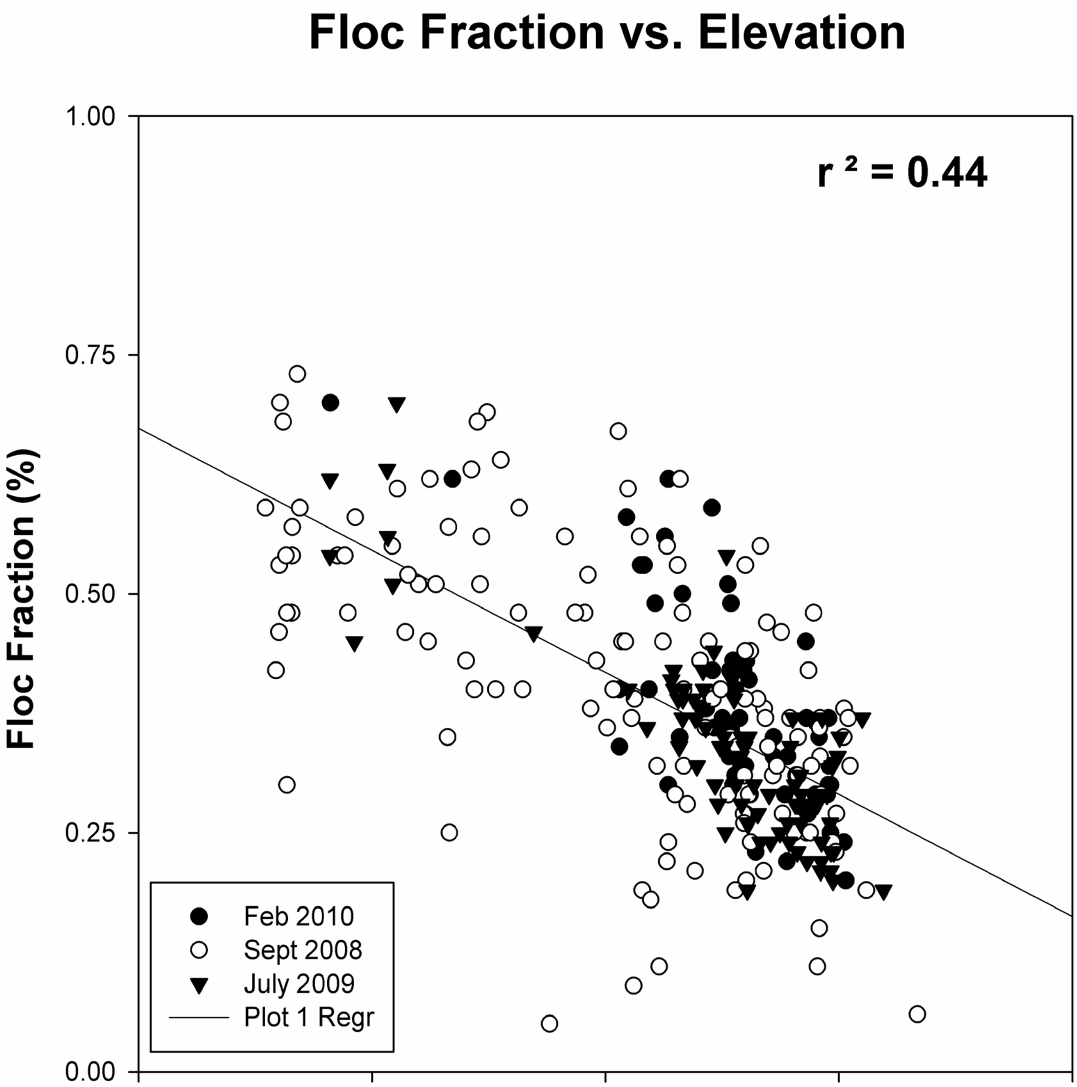

Figure 3 Scatter plot of floc fraction versus elevation on the tidal flat in Willapa Bay. Floc fraction is the fraction of sediment deposited in flocs as estimated by an inverse model of the disaggregated inorganic grain size (DIGS) distribution (cf. Curran et al., 2004) Data from 3 surveys are shown: dark circles, February 2010; dark triangles, July 2009; and open circles, September 2008. Floc fraction decreases with increasing elevation on the flats. A linear regression indicates that 44% of the variability in floc fraction is explained by elevation. Elevation data are derived from a NOAA Lidar survey of southern Willapa Bay. The Lidar datum is NAVD88 and differs from the mean water level zero datum used in Figure 4.

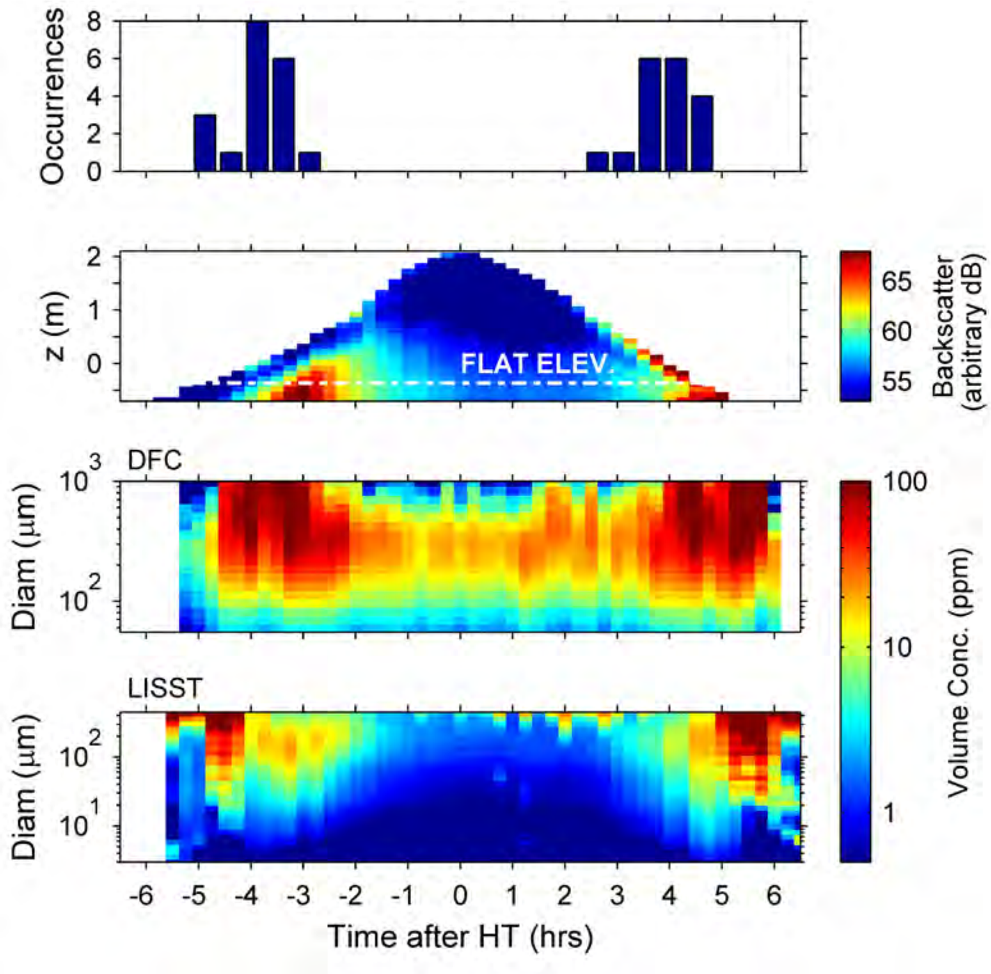

Figure 4. Occurrences of peak flood velocities, averaged acoustic backscatter and particle size and concentration in the channel plotted versus time relative to high tide. In the top panel, occurrences of the maximal flood and ebb velocities are shown versus time relative to high tide. In the second panel acoustic backscatter intensity is plotted. Approximate water level is indicated by the position of the top of the colored portion of the image. Data are binned and averaged according to time relative to high tide. In the middle and bottom panels, averaged particle concentrations estimated with the digital floc camera and the LISST-100X Type C, respectively, are plotted versus time relative to high tide. Warm colors indicate higher particle concentrations, as shown by the color bar on the right. Particle diameter is shown on the y axis. The elevation of the flat is shown as a white dashed line in the second panel. In general, acoustic backscatter intensity and large-particle concentrations peaked at the same times as peaks in flow speed. These peaks in flow speed occurred when water flowed onto and off of the flats. Acoustic backscatter and concentration of large particles decreased at high slack water, likely due to deposition.

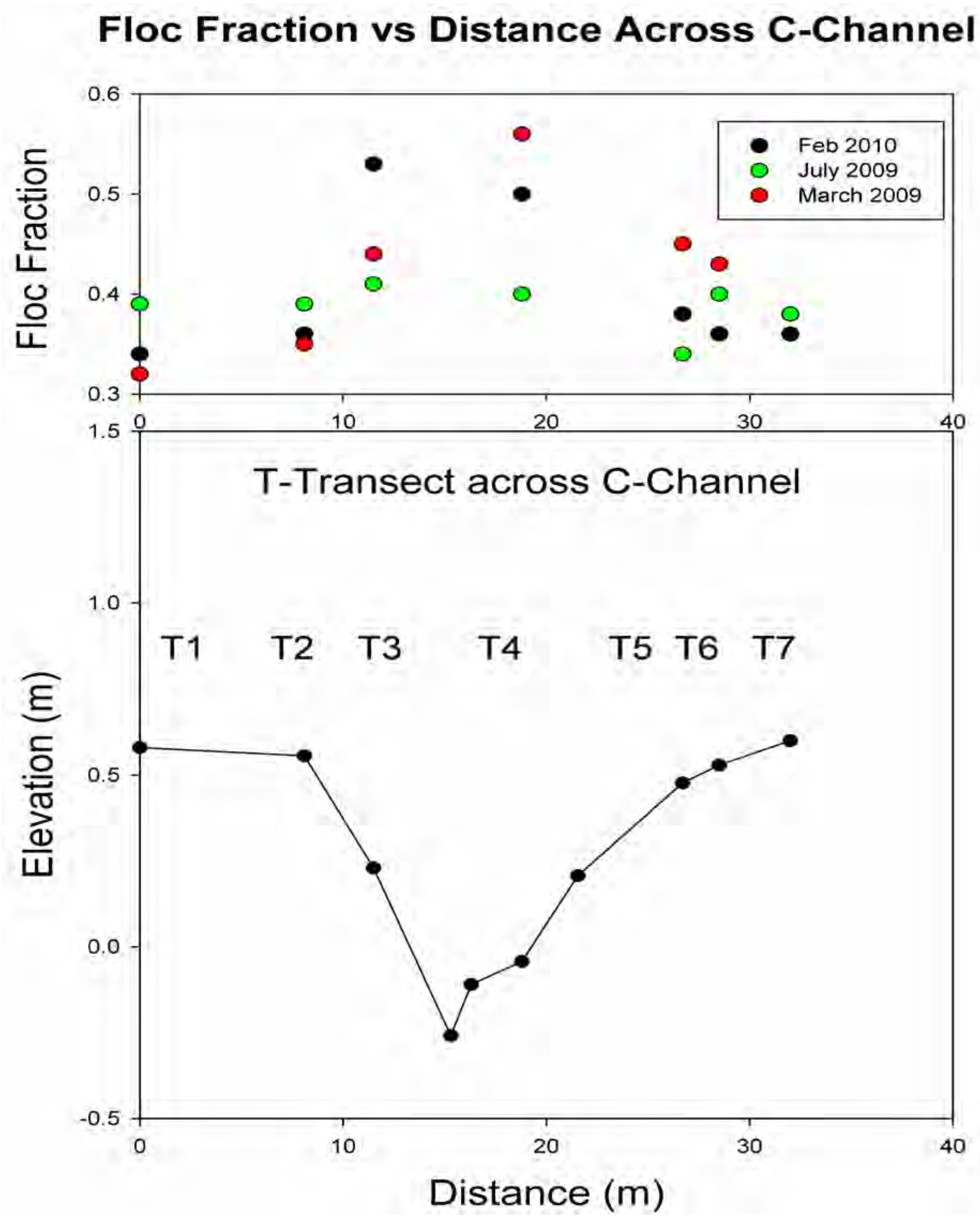

Figure 5. A plot of the T-transect across C-Channel, one of the larger secondary channels in the the Shoalwater Bay tidal complex. Panel A is a plot of floc fraction values from March 2009, July 2009, and February 2010 vs. distance across C-Channel in meters. The lower panel shows the cross section across C-Channel at the T-Transect. In summer floc fractions on the flat and in the channel are similar. In winter floc fractions on the flat are similar to summer, but floc fractions in the channel and on the channel flanks are higher.

PUBLICATIONS

Barry, M. A., B. D. Johnson, B. A. Law, V. Page, B. P. Boudreau, P. S. Hill and R. A. Wheatcroft, 2011, submitted. Sedimentary and geo-mechanical properties of Willapa Bay tidal flats, *Continental Shelf Research*. [submitted, refereed].

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Wiberg, P. L., B. A. Law, R. A. Wheatcroft, T. G. Milligan, P. S. Hill, 2011, submitted. Seasonal variations in erodibility and sediment transport potential in a mesotidal channel-flat complex, Willapa Bay, WA, *Continental Shelf Research.* [submitted, refereed]